Cloud structure from simultaneous ground-based measurements of fluxes and radiances

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KNMI - Cabauw (The Netherlands)

(51.971 °N, 4.927 °E)

Cabauw Experimental Site for Atmospheric Research (CESAR*):

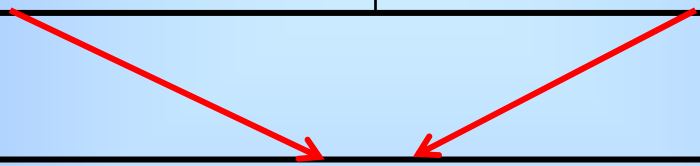
- 213m measurement tower
- BSRN measurement site (Cab)
- Atm. boundary layer research
- Gnd. based remote sensing:
  - (Doppler, scanning) Radars**
  - 7 channel scanning MWR
  - MP Lidar (later: Raman Lidar)
  - MFRSR
  - Aeronet site + PFR (expected ’07)
  - 2NFOV (planned)
- “Evergreen” surface albedo
- Responsibility: Reinoud Boers

* http://www.cesar-observatory.nl/

** not all of them yet operational

Cloud optical depth retrievals by combining solar radiation measurements and RT calculations

Some drawbacks of individual methods	
Retrievals using *hemispheric fluxes* affected by broken cloudiness (e.g. Boers et al. 2000)	Retrievals using *2NFOV radiances* degraded by cloud edges and clear-sky contamination (Chiu et al. 2006)



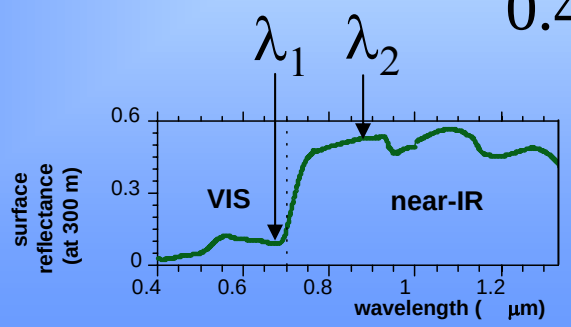
Merge methods: COUPLED
Chiu et al. 2006: best results for • broken clouds (cloud cover << 1) • low optical depth (τ < 30) • large spectral contrast in surface albedo (NDVI > 0.4)

COUPLED “retrieval space”

0.0 1.0

“low”	cloud cover
$\tau < 30$	cloud optical thickness
NDVI (spectr. surface albedo contrast)	

0.4



$\lambda_1 = 0.67$ μm: $\rho_{0.67} = 0.05\text{-}0.10$

$\lambda_2 = 0.87$ μm: $\rho_{0.87} = 0.25\text{-}0.55$

2NFOV + MFRSR ("COUPLED") cloud retrieval method

(Knyazikhin and Marshak, 2005; Barker and Marshak, 2001)

$$I_\lambda = I_o + \rho_\lambda I_s F_\lambda$$

$\lambda_1 = 0.67\ \mu m$
$\lambda_2 = 0.87\ \mu m$

from 2NFOV

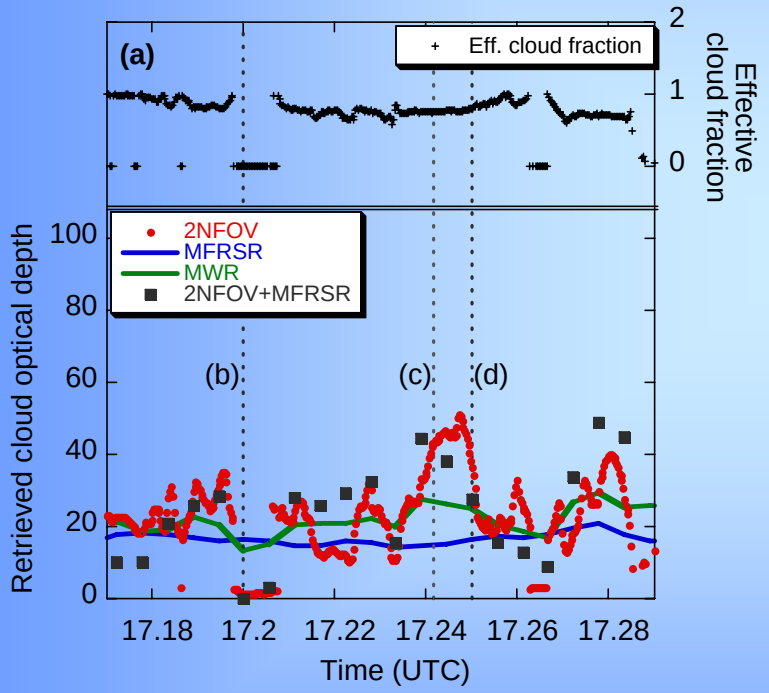
$$I_s(\tau) = \frac{I_{0.87} - I_{0.67}}{\rho_{0.87} F_{087} - \rho_{0.67} F_{067}}$$

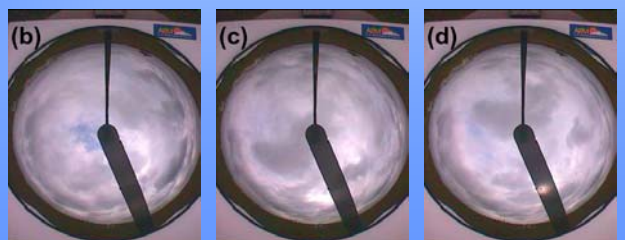
from MODIS & MISR or ARM meas.??

from MFRSR

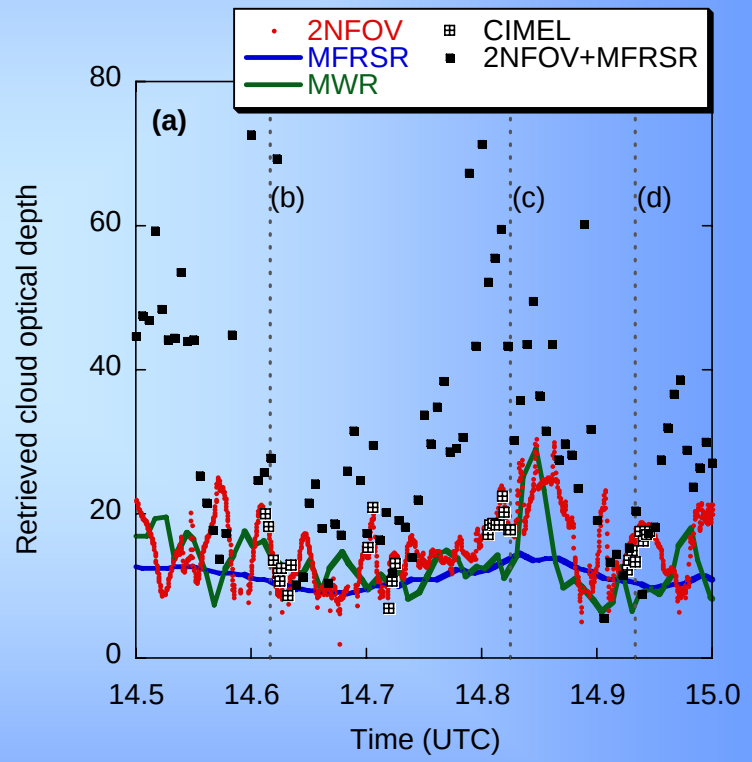
2 Examples (stable and unstable)

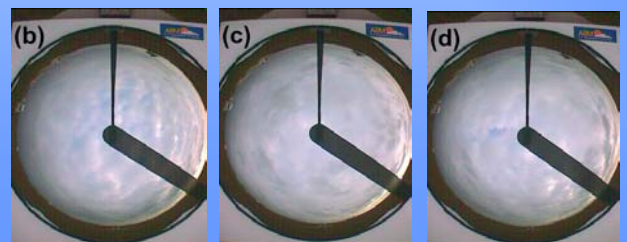
Oct. 28, 2004;
SZA=52,
ρ_{RED} = 0.13, ρ_{NIR} = 0.28





Nov. 11, 2004;
SZA=70-75,
ρ_{RED} = 0.17, ρ_{NIR} = 0.36



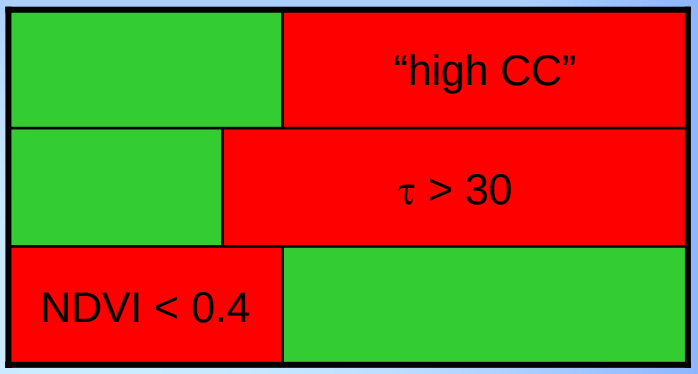


A few specific issues related to the REDvsNIR and COUPLED methods

cloud radiative transfer	Cloud optical prop. different in red (λ=670nm) and NIR (λ=870nm) spectral regions, e.g. phase function
cloud cover and/or cloud inhomogeneity	COUPLED retrieval algorithm based only on plane-parallel RT calculations, i.e. suppressing 3D structure of cloud field
COUPLED retrieval method	The 2-valued retrieval “REDvsNIR” is reduced to a single index retrieval “COUPLED”, i.e. increasing ambiguity

On the way to an improved COUPLED method

How to get stable retrievals under all conditions?

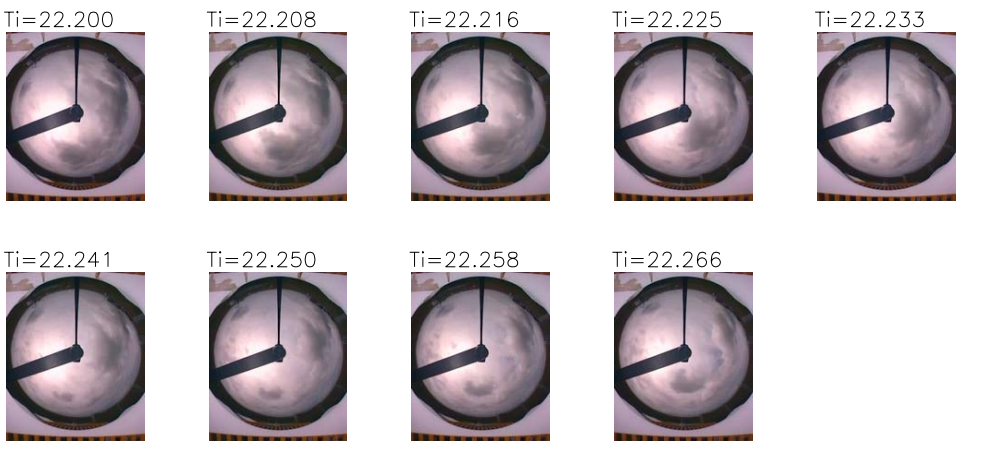


Searching for the extra amount of information: taking a closer look on cloud structures

- 3D view of REDvsNIR: adding fluxes
- Cloud mapping: study of trajectories
- Reviewing the single index retrieval

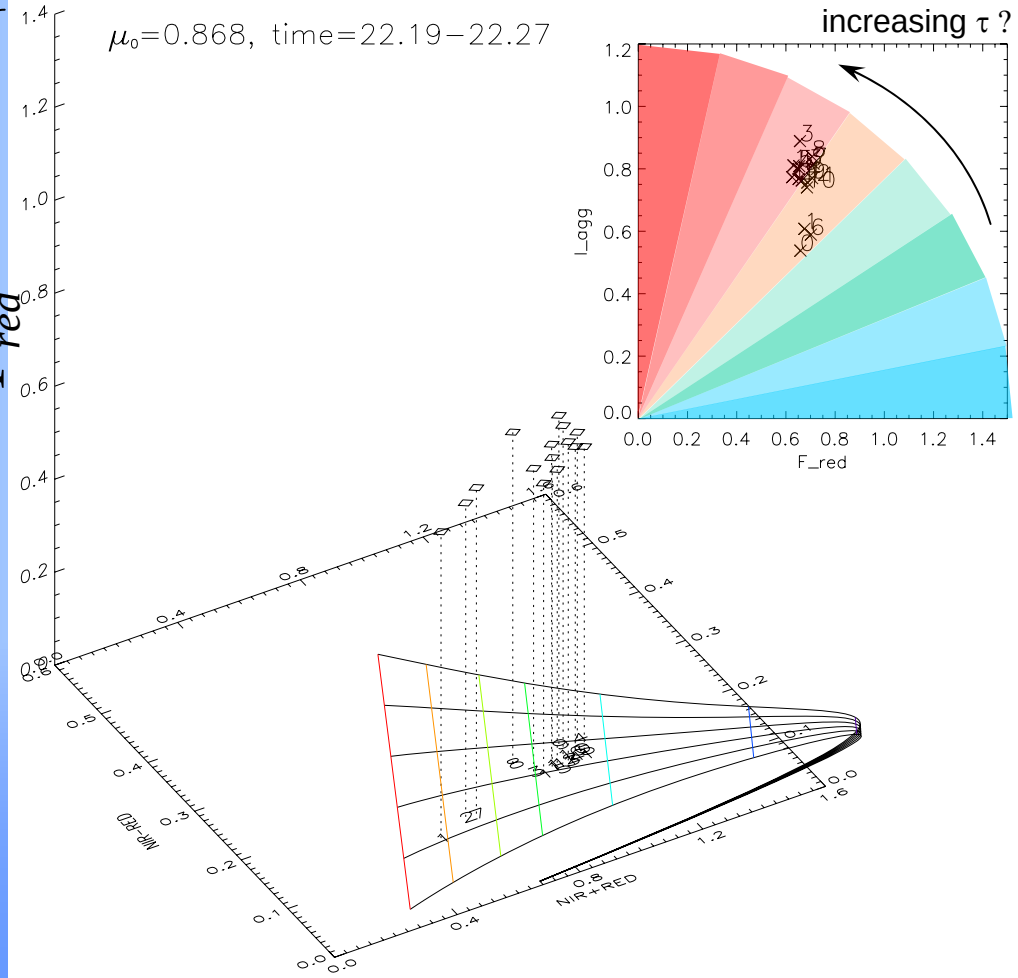
“low cloud structure”

- clustered REDvsNIR
- clustered I_s/F
- small fluxes



TSI

REDvsNIR LUT

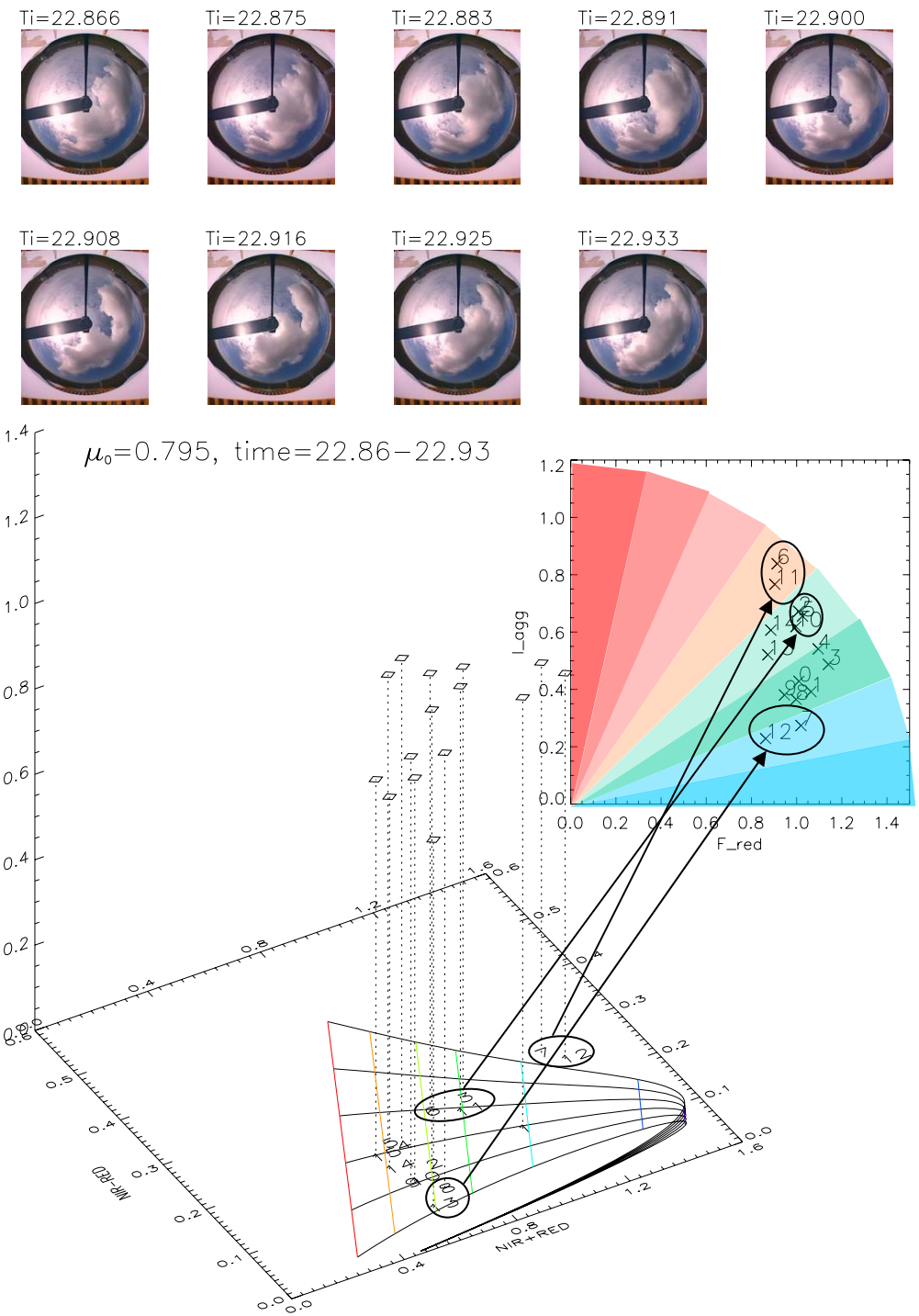


$$\frac{I_s(\tau)}{F_{red}(\tau)}$$

“time” or “Ti”: decimal UTC

“large flux”

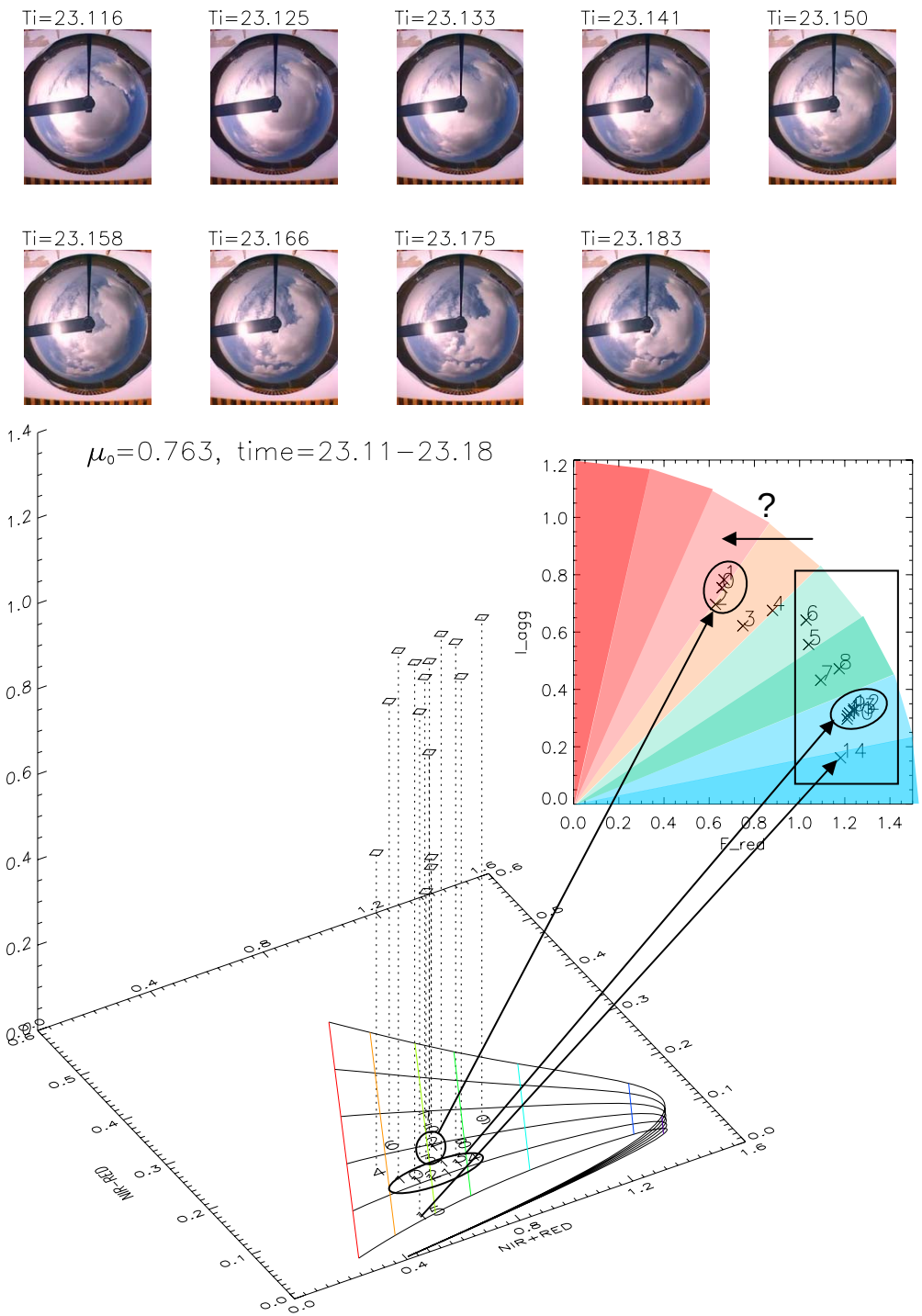
- scattered REDvsNIR
- vertically alligned I_s/F
- large τ (> 30)
- large fluxes
- cloud edge effect



decreasing CC

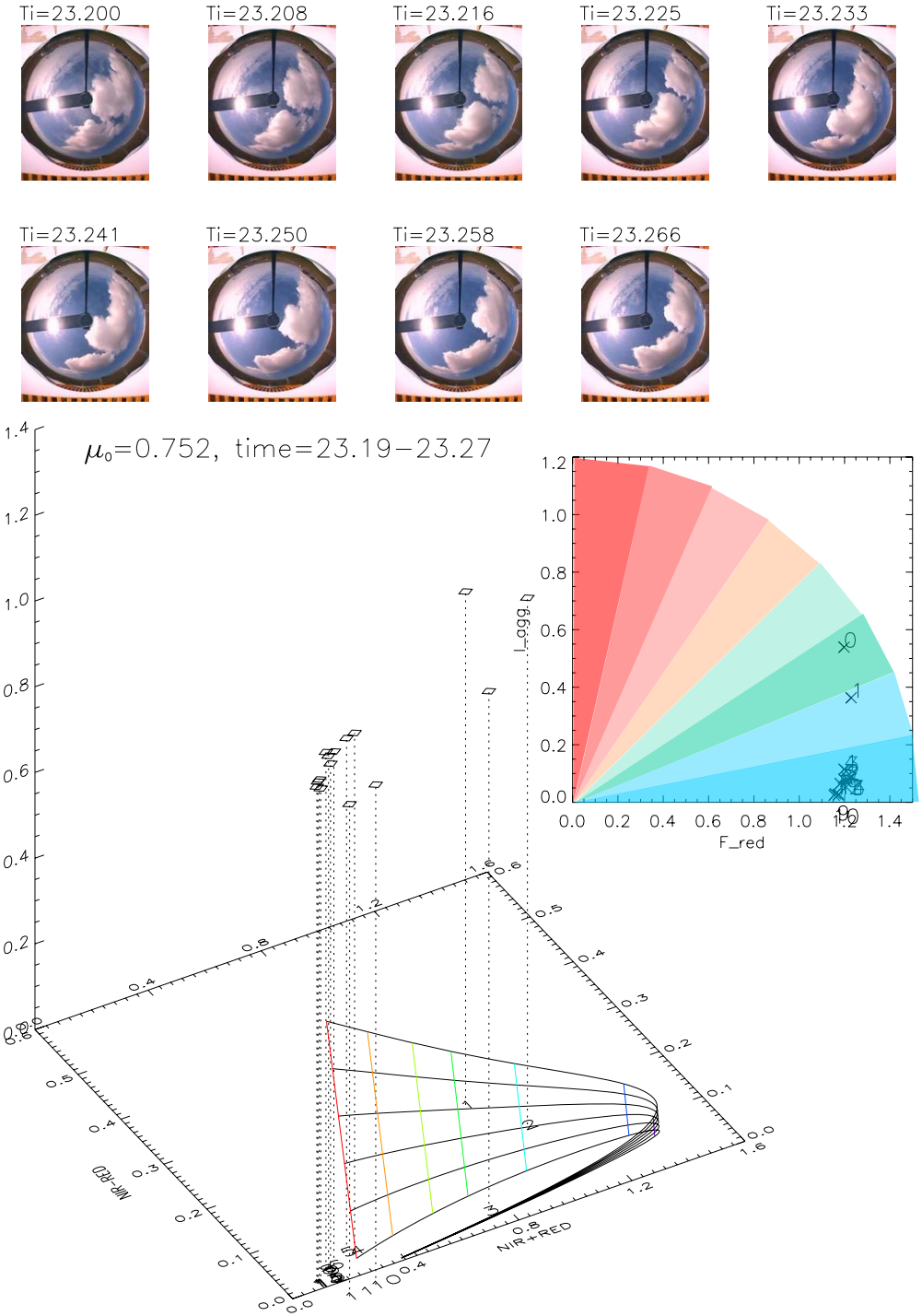
“trajectory”

- scattered REDvsNIR
- vert. and horiz. I_s/F
- constant τ (rel. large)
- variable fluxes
- ? : interesting trajectory



“clear vertical view”

- small REDvsNIR
- vertical I_s/F
- $\tau = 0$ (LUT)
- “not interesting” yet (no contribution from REDvsNIR)



Concluding remarks

“cloud-trajectory atlas”: tool to study cloud structure in combination with radiance and flux measurements

searching for extra amount of information using fluxes in addition to radiances: new “free parameter” available?

attempt to go from single index retrieval to multiple value retrievals: remove ambiguity